Nanofabrication Based on Template Synthesis for Sensing and Magnetism Applications

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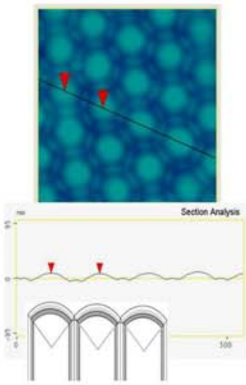
Motivation

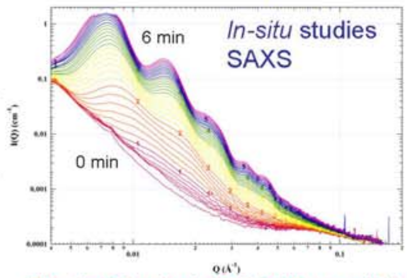
Anodized aluminum oxide (AAO) membranes have long been used for separation and surface protection. In order to develop new applications such as catalyst support (Poster: M. Pellin), substrates for chemical sensors, shadow masks for nanodots for photonics, and templates for nanowires, nanotubes, and nanowells toward electronic and magnetism applications, we investigated the intrinsic properties and the formation process of AAO.

Accomplishments

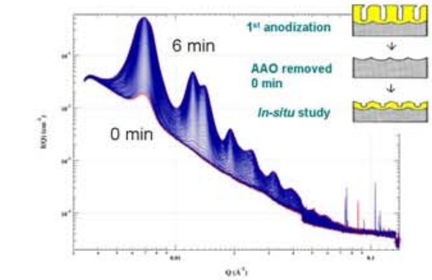
Template structure – An AFM image of AAO membrane, barrier side, after 30 min. chemical etching revealed an underlying double hexagon nanostructure. This unique structure consists of hexagonal cells with pure alumina in the cell wall (white area in the sketch) and oxalate contaminated alumina (gray area). This information explains different etching rates in the cell walls and provides practical guidelines for the control of pore opening through chemical etching.



Template formation process –



The first 6 minutes of AAO growth in oxalic acid at 40 V showing pattern developed but not ordered.



The first 6 minutes of pre-patterned AAO growth in oxalic acid at 40 V showing highly ordered hcp pattern.

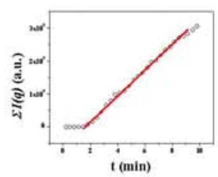
GISAXS Analysis

$$I(q)_{q\to 0} \propto N \cdot V_{cylinder}^2 = N \cdot \pi^2 R^4 H^2$$

and $I(t)_{q\to 0} \sim k \cdot t$

Therefore, $H(t) \sim \sqrt{t}$

$I(q)_{q\to 0}$	Scattering intensity
N	Number of pores
$V_{cylinder}$	Volume of a pore
R	Radius of a pore
H	Height of a pore

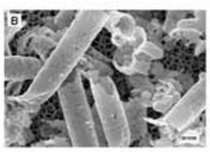


Major findings:

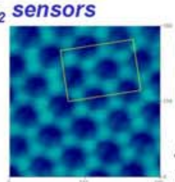
- Pore growth along lateral direction is fixed under constant potential
- Pore grows along the vertical direction as $\sqrt{t}$
- Pores self-assemble and form ordered structures (slow)
- With pre-patterned surface, the pores grow immediately.

Implication: The pre-patterned surface will facilitate the formation of smaller or larger ordered structures that are difficult to prepare directly.

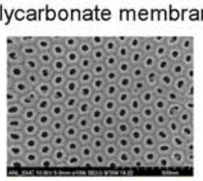
Nanowells/nanotubes H_2 sensors



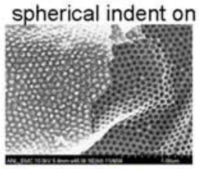
600 nm Pd nanotubes from polycarbonate membrane



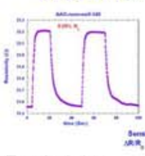
AFM image of nanowells showing 6 humps around each well due to hemi-spherical indent on surface



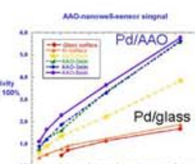
10 nm Pd thin film over AAO nanowell



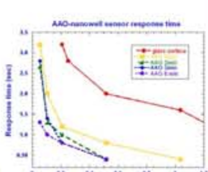
Released Pd thin film showing nanowell imprint



Resistivity increases with H_2 on and returns to R_0 with H_2 off.



Pd over AAO nanowells showing higher sensitivity than Pd/glass.

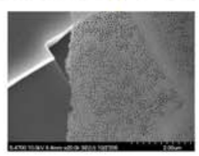


Pd/AAO nanowells showing much faster response time

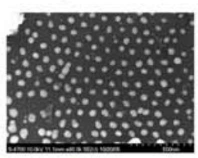
Pd/AAO nanowells and nanotubes are being evaluated as ultra-sensitive H_2 sensors for corrosion prevention.

Future Directions

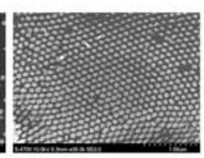
AAO mask for nanoparticle arrays



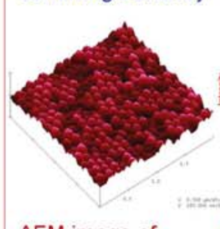
Thin AAO membranes are good shadow masks.



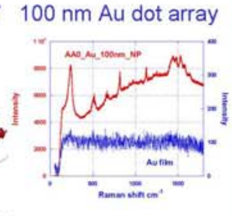
50 nm Ag dot array



100 nm Au dot array

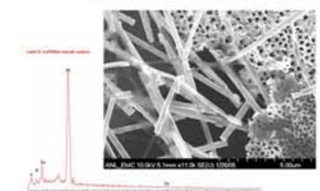


AFM image of Au nanodots on Si - a good SERS active substrate



Ag and Au nanodot arrays are ideal for localized surface plasmon resonance Raman studies.

Core-Shell nanowires

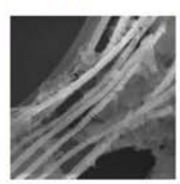


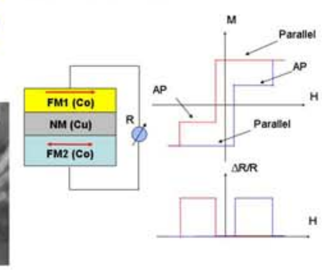
Goal: Core-shell nanowires for better magnets

CoPt (Hard) shell

Co (Soft) core

Multi-segment nanowires





Partially etched 50 nm Co/Cu nanowires with 20/20 nm segments.

Goal: Multi-segment nanowires for GMR effect and novel memory

S. Yu, U. Welp, L. Z. Hua, A. Rydh, W. K. Kwok, H.-H. Wang, Chem. Mater. 17 3445 (2005)

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